BriX one-day meeting

Monday, 23rd November 2015
Instituut voor Kern en Stralingsfysica, Room 03.84
Department of Physics and Astronomy, KU Leuven

BOOK OF ABSTRACTS

Wouter Ryssens (ULB), M. Bender (CENBG), P.-H. Heenen (ULB)

Symmetry unrestricted Skyrme mean-field study of heavy nuclei.

In the light of recent experimental developments, increasing attention is devoted to nuclear phenomena related to rotational excitations of more exotic intrinsic nuclear configurations that often lack certain symmetries often present in the majority of nuclei. Examples include configuration with a non-vanishing octupole moment.

In order to describe this kind of states, we have developed a new method for self-consistent mean-field calculations, using effective Skyrme interactions in a coordinate-space representation. The code is based on the same principles as the EV8 code [1], but all symmetry assumptions assumed in EV8 (e.g. parity) can be individually relaxed. Another important generalization is the replacement of the HF+BCS by the full machinery of Hartree-Fock-Bogoliubov transformations.

We will report progress on the first applications that are currently underway and more specifically the description of Radium isotopes and their neighboring isotopes. Both the description of low-lying negative parity states as well as the description of asymmetric fission necessitates the inclusion of mean-field configurations that break parity.

[1]P. Bonche, H. Flocard, P.-H. Heenen, Comp. Phys. Comm. 171 (2005) 49; W. Ryssens, V. Hellemans, M. Bender, P.-H. Heenen, Comp. Phys. Comm. 187 (2015) 175.

Mustapha Laatiaoui (HIM/GSI)

First observation of an atomic level in the element Nobelium.

Laser spectroscopy of elements beyond Fermium (Z=100) is nowadays considered to be one of the most fascinating and simultaneously challenging tasks in atomic physics.

In particular, the online production rates of a few atoms per second at most render any optical spectroscopy in that region of the chart of nuclei extremely difficult. However, such studies are of special importance as they would shed light on the impact of relativistic- and QED-effects on the electronic structure of such atoms, for which so far no experimental data exist. Laser spectroscopy of the element Nobelium (Z=102) has long been anticipated at GSI in Darmstadt [H. Backe et al., EPJD 45 (2007) 99].

In my talk I will summarize the pioneering work in this field of research and report on the first observation of an atomic level in ^{254}No.

Camilo Granados (KULeuven - IKS)

Resonant ionization spectroscopy of Ac isotopes: an update.

Results on the Actinium in-gas-cell and in-gas-jet ionisation spectroscopy will be presented. Information about the nuclear physics results will be discussed. Status and future plans of the IGLIS laboratory as well as its role in the on-line spectroscopy experiments will be discussed.

Gregory Farooq-Smith (KULeuven - IKS)

Results on Francium isotopes at the collinear resonance ionisation spectroscopy (CRIS) setup.

The Collinear Resonance Ionisation Spectroscopy (CRIS) setup is an experiment situated at ISOLDE-CERN, examining ground-state properties of exotic Francium isotopes. Yields as low as 100 ions/second have been reported with high efficiency and low background; this is achieved by the coupling of collinear laser and resonance ionisation spectroscopy techniques [1]. In addition, pure state beams have been examined even in the midst of isobaric contamination: previous highlights include the separation of overlapping ground and isomeric states in ^{202}Fr and ^{204}Fr with complementary decay spectroscopy techniques [2, 3], and reaching the very neutron-rich isotopes of Francium, up to ^{231}Fr [4]. Recently, the use of high-resolution laser techniques has allowed the quadrupole moment of ^{219}Fr to be determined for the first time [5]. In addition, the ability to run at an improved duty cycle has resulted in the first measurements of ^{214}Fr, which with a half-life of 5 ms represents the shortest-lived isotope to be measured online with laser spectroscopy [6]. Laser-assisted nuclear decay spectroscopy of ^{206}Fr has also been performed at the decay spectroscopy station [7]. All of these results will be presented, in light of the improvements made at the CRIS setup.

[1] K. T. Flanagan et. al., Phys. Rev. Lett. 111, 212501 (2013)
[2] K. M. Lynch et. al., Phys. Rev. X 4, 011055 (2014)
[3] M. M. Rajabali et. al., Nucl. Instrum. Meth. A 707, 35 (2013)
[4] I. Budincevic et. al., Phys. Rev. C 90, 014317 (2014)
[5] R. P. de Groote et. al., Phys. Rev. Lett. 115, 132501 (2015)
[6] G. J. Farooq-Smith et. al., In Preparation (2015)
[7] K. M. Lynch et. al., In Preparation (2015)

Livio Filippin (ULB)

Accounting for core-core effects in multiconfiguration calculations of isotope shifts.

When the effects of the finite mass and the spatial charge distribution of the nucleus are taken into account in a Hamiltonian describing an atomic system, the isotopes of an element have different electronic energy levels [1]. The isotope shift (IS), which consists of the field shift and the mass shift, plays a key role in extracting nuclear properties of an isotope such as its nuclear mean-square charge radius $\langle r^2 \rangle$ [2]. For a given atomic transition k with frequency ν_k, it is assumed that the *electronic response* of the atom to variations of the nuclear mass and charge distribution can be described by only two factors: the mass-shift factor M_k and the field-shift factor F_k, respectively [2].

Five transitions are of interest for laser spectroscopy experiments of neutral aluminum (Al I) radioactive isotopes in order to determine their nuclear properties: $3s^2 3p\ ^2P^o_{3/2} \rightarrow 3s^2 4s\ ^2S_{1/2}$ (396.26 nm), $3s^2 3p\ ^2P^o_{1/2} \rightarrow 3s^2 4s\ ^2S_{1/2}$ (394.51 nm), $3s^2 3p\ ^2P^o_{1/2} \rightarrow 3s^2 3d\ ^2D_{3/2}$ (308.30 nm), $3s^2 3p\ ^2P^o_{3/2} \rightarrow 3s^2 3d\ ^2D_{3/2}$ (309.37 nm) and $3s^2 3p\ ^2P^o_{3/2} \rightarrow 3s_2 3d\ ^2D_{5/2}$ (309.36 nm). For neutral magnesium (Mg I), two well-known transitions from experiments [3,4] are the following: $3s^2\ ^1S_0 \rightarrow 3s^3 p\ ^3P^o_1$ (457.24 nm) and $3s^2\ ^1S_0 \rightarrow 3s^3 p\ ^1P^o_1$ (285.30 nm).

We perform ab initio calculations of IS factors using the multiconfiguration Dirac-Hartree-Fock (MCDHF) method implemented in the Ris3/Grasp2K [1,5]. The strategy adopted is based on the estimation of the expectation values of the one- and two-body recoil Hamiltonian for a given isotope, including the Shabaev relativistic corrections [6], combined with the calculation of the theoretical total electron densities at the origin. Different correlation models are explored in a systematic way to determine a reliable computational strategy. The aim of this work is to study the effect of including core-core correlations on the numerical results of both Mg I and Al I IS factors. The correlation model considered for Al I can be validated with a similar calculation on Mg I thanks to a comparison with previous theoretical results [7] and experimental values from Refs. [3,4].

[1] C. Nazé et al., Comput. Phys. Commun. 184, 2187 (2013).
[2] B. Cheal, T. E. Cocolios, and S. Fritzsche, Phys. Rev. A 86, 042501 (2012).
[3] U. Hallstadius, Z. Phys. A 291, 203 (1979).
[4] E. J. Salumbides et al., Mon. Not. R. Astron. Soc. 373, L41-L44 (2006).
[5] P. J onsson et al., Comput. Phys. Commun. 184, 2197 (2013).
[6] V. M. Shabaev, Theor. Math. Phys. 63, 588 (1985); Sov. J. Nucl. Phys. 47, 69 (1988).
[7] J. C. Berengut, V. V. Flambaum, and M. G. Kozlov, Phys. Rev. A 72, 044501 (2005).

Alexandra Zadvornaya (KULeuven - IKS)

First results on visualization of the acetone supersonic gas jet by means of the PLIF-technique.

The in-gas laser ionization and spectroscopy (IGLIS) method that has been developed at KU Leuven allows to perform laser spectroscopy of short-lived radioactive isotopes created in different types of nuclear reactions. To realize the advantages of in-gas-jet ionization, the parameters of supersonic gas flow after the de Laval nozzle should be carefully chosen and checked prior to the experiment. Planar Laser-Induced Fluorescence (PLIF) technique can be applied in order to visualize the gas jet. The investigated atoms are seeded in the gas flow inside the gas cell. The atoms coming out of the nozzle are irradiated by a planar laser beam and the emitted fluorescence light is recorded by a camera. By scanning the frequency of the narrow band laser around the resonance transition the information about velocity, temperature and density across the gas jet can be obtained. The first tests on the visualization of the supersonic gas jet were performed with acetone, which has high vapor pressure and low toxicity. Additionally, absorption and emission lines of acetone are in UV and VIS ranges, which can be reached with our lasers and camera. In the present contribution, the first tests on the visualization of the acetone gas jet after the `de Laval nozzle` at IGLIS laboratory at KU Leuven will be presented. The experimental setup that include the gas handling- and pump system, the laser and the detection system will be described.

Riccardo Raabe (KULeuven - IKS)

Physics with active targets.

Active targets are gaseous time-projection chambers designed for reaction and decay studies with nuclei far from stability. In reaction studies, the nuclei of the detection gas are also the targets of the reaction of interest, allowing for a large target thickness without compromising on energy resolution. This class of instruments, initially developed for high-energy physics, has found profitable applications in medium- and low-energy nuclear physics. These detectors are potentially very versatile: they can function as stand-alone charged particle detectors, or they can be coupled to arrays of other charged-particle or gamma-ray detectors to expand their scope.

In Leuven we are working at the development of active targets to investigate different physics topics. The main project is SpecMAT, which aims at studying the spectroscopy of nuclei very far from stability in the Ni and Pb region by measuring transfer cross sections. The ACTAR TPC detector will be mainly focusing on resonant reactions and decay studies. With a different configuration, another active target will be realised to study giant resonances in isotopic chains.

Jacobus Andreas Swartz (KULeuven - IKS)

Scintillator tests for SpecMAT.

The project SpecMAT, funded by an ERC grant, seeks to supplement an active gas target detection system for nucleon transfer reactions with a sensitive array of gamma-ray detectors. The entire ensemble must operate in a high magnetic field, which makes it possible to infer information about each particle's mass, charge and energy by looking at the radius of curvature and length of each particle's track. Tests have been performed with prototype detectors of both $LaBr_3$ and $CeBr_3$ to determine the optimum combination of materials, dimensions and electronics to be used in the final SpecMAT scintillator array, bearing in mind the difficulties associated with working in a magnetic environment. This talk will present results of these tests.

Wim Cosyn (University of Ghent)

Probing nuclear short-range correlations in two-nucleon knockout reactions.

We show how two-nucleon knockout reactions in the intermediate energy regime can offer detailed information about short-range nuclear structure across the whole mass range. We compare recently obtained experimental data with calculations from the group at Ghent University. These calculations start from the so-called zero-range approximation (i.e. short-range correlated nucleons originate from IPM pairs with relative distance approaching zero) and take into account possible final-state interactions effects and account for the full phase space of the experiment.

Andres Illana Sison (KULeuven - IKS)

First Miniball experiment at HIE-ISOLDE.

After 2 years of shut-down, the post acceleration beam line at ISOLDE has been renewed (now it is called HIE-ISOLDE) and the MINIBALL spectrometer has been reinstalled. MINIBALL will benefit from the energy upgrade enabling multi-step Coulomb excitation experiments and few-nucleon transfer reactions studies of heavy nuclei. The first experiment, which was carried out a few days ago, was dedicated to the study of the evolution of the nuclear structure along the Zinc isotopic chain close to the doubly magic nucleus ^{78}Ni. The preliminary data from that experiment will be presented.

Matthias Verlinde, R.P. De Groote, G. Neyens (KULeuven - IKS)

Nuclear physics applications for STIRAP?

In experimental atomic physics and quantum optics many techniques and ideas are being developed which could potentially help improving nuclear physics laser spectroscopy techniques. My talk will focus on one of these techniques in particular, namely 'STIRAP'. 'STImulated Rapid Adiabatic Passage'. SITRAP, provides a way to achieve 100 percent efficient and robust population transfer between 2 atomic levels. This technique is already widely applied in solid state and molecular physics, and could present new applications for nuclear physics research. I will present the theoretical quantum mechanical foundations, supported by simulations, with a particular focus on practical concerns regarding the use of this technique in the typical situations encountered in laser spectroscopy for nuclear physics research.

Luca Egoriti, (SCK•CEN)

Tantalum-based high-porosity carbides for radioactive ion beam production at ISOL facilities.

The use of refractory metal targets in Isotope Separation On-Line (ISOL) facilities allows target operation under a higher maximum temperature inside the target. The positive consequences are (1) the possibility of increasing the incoming proton beam current and (2) the enhancement of diffusion and effusion processes. Therefore, the possibility of operating with a Tantalum Carbide target is appealing in the framework of an ISOL facility. Such a material is specifically of interest for high-power facilities like ISOL@MYRRHA. Current experimental programs at ISOL facilities are more and more focused on very short-lived isotopes, for which the efficiency of the release process (extraction of the isotopes out of the target material) is of primary importance. If this process is too slow, the isotopes decay before being extracted in a radioactive ion beam (RIB) and delivered to the experimental station. In TaC material, the in-grain diffusion of certain elements like rare earth elements is rather slow, as suggested in [1]. Improving the material structure to enhance fast diffusion is therefore an interesting development towards higher RIB yields. At SCK-CEN and in collaboration with the research group of Advanced Ceramics and Powder Metallurgy from KU Leuven, a feasibility study is being developed for investigating the improved performances of innovative TaC materials characterized by high porosity. The models developed for estimating the release of isotopes out of a target based on these new materials have been benchmarked with experimental data from metallic Tantalum targets operated at ISOLDE facility. The diffusion process has been treated analytically while effusion has been evaluated through Monte Carlo calculations which show results globally well in agreement with the experimental data. However reliable data on diffusion coefficients of the materials under investigation at high temperatures is currently lacking. A parametric study of the influence of the diffusion coefficient on the release of Li isotopes was then performed. This presentation will discuss the on-going feasibility study. Results of the benchmark exercise will also be presented.

[1] P. Hoff, O.C. Jonsson, E.Kugler, H.L. Ravn, Nucl. Instrum. Meth. B 221 (1984) 313

Maciej Perkowski (KULeuven - IKS)

Status of the miniBETA experiment.

MiniBETA is an experiment conducted with the collaboration of the Jagiellonian Institut. It was designed to make high precision (better than 1%) energy spectrum measurements in nuclear beta decay. A spectrum obtained in such a way can be compared with the simulated one based on the Standard Model (SM), with differences being attributed to the existence of exotic currents not included in the SM. MiniBETA consists of a compact modular reconfigurable drift chamber triggered by scintillators and controlled by a dedicated data acquisition (DAQ) system. During the talk the experimental results from the commissioning of the system, which has been ongoing at KU Leuven, will be presented.

Peter Koss (KU Leuven - IKS)

A Potassium magnetometry based current source for the nEDM experiment at PSI.

A permanent electric dipole moment of the neutron (nEDM) would be a source of CP violation and could shed some light on beyond standard model physics (BSM). Such BSM models predict an nEDM in the range 10^{-27} - 10^{-29} e cm while the standard model prediction is much lower (around 10^{-31} e cm). The search for an nEDM and the setting of new limits on its value is done with the Ramsey method of time separated oscillatory field. This method requires a very well-known magnetic field during the measurement cycles. This is typically done via magnetometers in the experimental volume which monitor the stability and the evolution of the magnetic field. The main field B_0 is produced by a dedicated current source. Thus the stability of B_0 is fundamentally limited by the stability of the current source. In the spirit of continual improvement of the experiment, we plan to build a new ultra-stable current source for our experiment. The idea is to use a commercial very low noise current source and to stabilize its output via a feedback loop. This feedback loop will be installed outside of the nEDM experimental volume. A dedicated coil will be placed in series to the main coil (producing B_0). There Potassium magnetometers will monitor drifts in current through drifts in the magnetic field. The feedback loop will correct for such drifts thus stabilizing the output current.